INVENTORY OF SLASH FUELS USING 3P SUBSAMPLING

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INTERMOUNTAIN FOREST & RANGE
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ABSTRACT

A recent large-scale study of prescribed broadcast burning in western Montana required the development of a system for inventory of clearcut logging slash fuels before and after fire treatment. The system is best suited for inventorying material which tends to be oriented parallel to the ground. The inventory system uses line intercept counts to compute fuel volume, weight, and surface area. 3P subsampling is used to inventory twigs (0-1 cm diameter). Data reduction was accomplished with specially written computer programs. When used with proper and sufficient subsampling for auxiliary, collateral data, the system is well suited for the inventory of slash fuels in many forest types.

OXFORD: 432:432.16. KEYWORDS: fire control, slash disposal (fuel reduction), fuel inventory, 3P subsampling, planar intercept sampling.

INTRODUCTION

A large-scale study of prescribed burning conducted in the larch--Douglas-fir type (SAF type 212:Society of American Foresters 1967, p. 46) in western Montana required the development of a system to inventory clearcut logging slash fuels both before and after treatment by broadcast fires of varying intensity. This paper describes the theory, sampling design, field procedures, and data processing programs that were developed for the inventory system applied on one hundred 2 1/2-acre plots. Plots were located on the four cardinal exposures and on slopes ranging from 10 to 70 percent to offer wide range of fuel loading. The experience gained in the installation and measurement of the approximately 7,000 sampling points involved in this study should be of value to others who may wish to quantify similar slash fuels.

The System in Brief

Basically, this system is best suited for inventorying materials, such as logging slash or windthrown stands, that tend to be oriented parallel with the ground. The method of inventory is a variation on the line transect technique of sampling. The theory of line-transect measurements views intercepted, horizontal fuel particles as representative of the total mat of fuel.

Determination of the proper level of sampling and subsampling intensity is achieved through the same techniques used in such other mensurational problems as timber cruising. On our experimental 2 1/2-acre plots, we found that 66 transects, each 1 m long, adequately represented slash components less than 10 cm in diameter. However, this sampling intensity may not be suitable at other locations or for other sampling objectives.

The system requires that certain basic information about fuel categories be determined. One such item is the mean diameter of particles in a size class for a given fuel. The necessary mean diameters for this study were generated by a procedure described later. In other timber types it will be necessary to generate mean diameters of fuel particles within each size class for each additional species of tree.

In the 3P subsampling system, line intercept counts are used to compute fuel volume, weight, and surface area. If duff (the partially decayed organic matter on the forest floor) weight per unit of ground area is desired, a duff weight per unit of volume (bulk density) relationship must be developed as outlined later in this text. Duff bulk density varies from stand to stand and even between exposures. When proper and sufficient subsampling for needed mean diameters and duff bulk density are used, slash fuels in many forest types can be described by the system outlined in this paper.

The Problem

Our purpose for inventorying the organic debris on logged sites was to assess the influence of fuel quantities on the energy released during prescribed broadcast fires. The rate of energy released from a given area of a fire is often called the fire intensity, and the size and geometry of fuel particles have an influence on it. Tree species differ in their branching habit, branch size, and leaf morphology, thus yielding various ranges of fuel sizes and loadings. Due to its matlike physical form, duff may also be a fuel that influences fire intensity. Because of the complex variations in fuel bed structure and composition, a simple expression of total fuel weight per unit area is not sufficient to describe the energy released from a prescribed fire.

Logging slash consists of the tops, limbs, and leaves of harvested trees. In addition, there are whole cull trees and logs, noncommercial trees which are felled during the harvest operation, and the existing organic forest floor. The forest floor has a highly irregular interface with the mineral soil accentuated by partially buried logs, decayed stumps, and protruding rocks.

Some of the more important factors which combine to complicate the fuel bed on any given clearcut site are:

1. Steep slopes may influence the orientation and distribution of fallen fuels.

2. Changes in exposure, even within short distances, may have a profound effect on site productivity, thus resulting in variations in fuels.

3. Trees can be felled so that all tops are parallel and lying on the contour, or they may be felled in a random fashion.

4. Skid trails may be tractor width, scraped to bare mineral soil; or they may be narrow, multiple strips characteristic of cable skidding. They can alter fuel distribution considerably.

5. Tree-length skidding often results in disproportionate accumulations of treetops and limbs directly beneath jammer or high-lead settings, or in rows between a network of skid trails.

6. Utilization standards profoundly influence the amount of larger fuel particles left on a site.

Thus, a sufficiently definitive inventory was needed to allow statistical comparisons between various fuel complexes and resulting fire characteristics, responses, and effects.

Literature Review

Recent measurements of logging slash characteristics in the interior Douglas-fir forest type employed destructive sampling methods (Steele and Beaufait 1969). Data collected from forty 2-m-long transects revealed that:

1. Particles larger than 10 cm diameter are rarely consumed by broadcast fires.

2. High internal variation in slash fuel loading dictates the need for many measurement points within a fuel bed to reduce errors of estimate.

3. Destructive sampling, at the density required by the internal variability, results in alteration of the experimental material, and is uneconomical on large-scale studies.

4. Nondestructive sampling of logging slash using vertical planar transects is precise enough to provide inputs for fire intensity comparisons.

5. Short transects are easier to tally accurately than are long transects.

Warren and Olsen (1964) applied long-line transect procedures to an inventory of logging slash in New Zealand. Their study pointed out the importance of particle orientation with reference to the transect line. In 1967, Beaufait[2] outlined a method for describing all slash and duff components through a series of randomly oriented, 1-m-long vertical planes. VanWagner (1969) derived an equation useful in inventory of randomly-oriented slash particles. Brown (1971) expanded the mathematical model to accept a wide range of fuel conditions having particles of several shapes intersecting the sampling plane at all possible angles.

Slash sampling is painstaking and time-consuming work. Sound statistical procedures and efficient subsampling are required to reduce the costs of inventory. Counting up to 1,000 particles on each of thousands of transects is not economically feasible. The system described in this paper substitutes a combination of estimates and counts corresponding to Grosenbaugh's (1965) 3P subsampling procedures. A description of the method and our refinements is given later.

Likewise, it is impractical to count tree needles and components of the forest floor on a large number of transects. Fahnestock (1960) and Chandler (1960) published tables of needle weight for many western conifers. We emulated Brown's (1965) work with red and jack pine by subsampling needle-weight to branch-weight ratios, handling each species separately. Equations for calculating volume and surface area of needles per unit of branchwood were published by Brown (1970).

Duff is best characterized by an empirical relationship between duff depth and duff weight. Weight per unit of volume, or gross bulk density, can thereby be computed.

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[2]William R. Beaufait. Prescribed fire cooperative study--Region 1-INT. Study Plan No. FS-INT-2102-12, on file at the Northern Forest Fire Laboratory, Intermountain Forest and Range Experiment Station, Missoula, Mont. 1967.

INVENTORY DESIGN

Layout of Sampling Areas

Three blocks of study units--Coram, Miller Creek, and Newman Ridge--were sampled during development of the inventory system. The sampling points were distributed mechanically over each of the experimental burning units. Figure 1 illustrates the three sampling patterns. At Coram, sampling points were placed at the intersections of a 1-chain grid superimposed on a 25-acre unit of slash. X and Y base lines of the grid were located at random. Each sampling point was designated by its X and Y values. The square grid layouts used at Miller Creek and Newman Ridge proved to be superior from a practical standpoint in the field.

At our second study block, Miller Creek, we chose to sample intensively the fuels in a central 2 1/2-acre plot within each 10-acre unit, leaving the border area as an isolation strip. On each of the first five units, 231 points were sampled. Analyses of these five units indicated that sample size on the remaining 55 units of this study could be reduced to 66 points without significant loss in precision. The subsampling ratio for sampling the twigs (<1 cm diameter) was determined from analysis of these first five units. At Newman Ridge three 2 1/2-acre plots, each having 66 sample points, were installed in each of the large units (fig. 1). Again, the required number of points may be different at other locations or for other objectives.

Fuel Size Classes

Western coniferous slash fuels may be conveniently grouped into five classes of different physical characteristics:

1. *Leaves (needles)*, suspended above the forest floor

2. *Duff* (the partially decayed organic material in the F and H layers of the forest floor)

3. *Twigs*, woody particles (<1 cm diameter)

4. *Branches*, woody particles (1-10 cm diameter)

5. *Stems*, the tops of trees, or cull logs (>10 cm diameter)

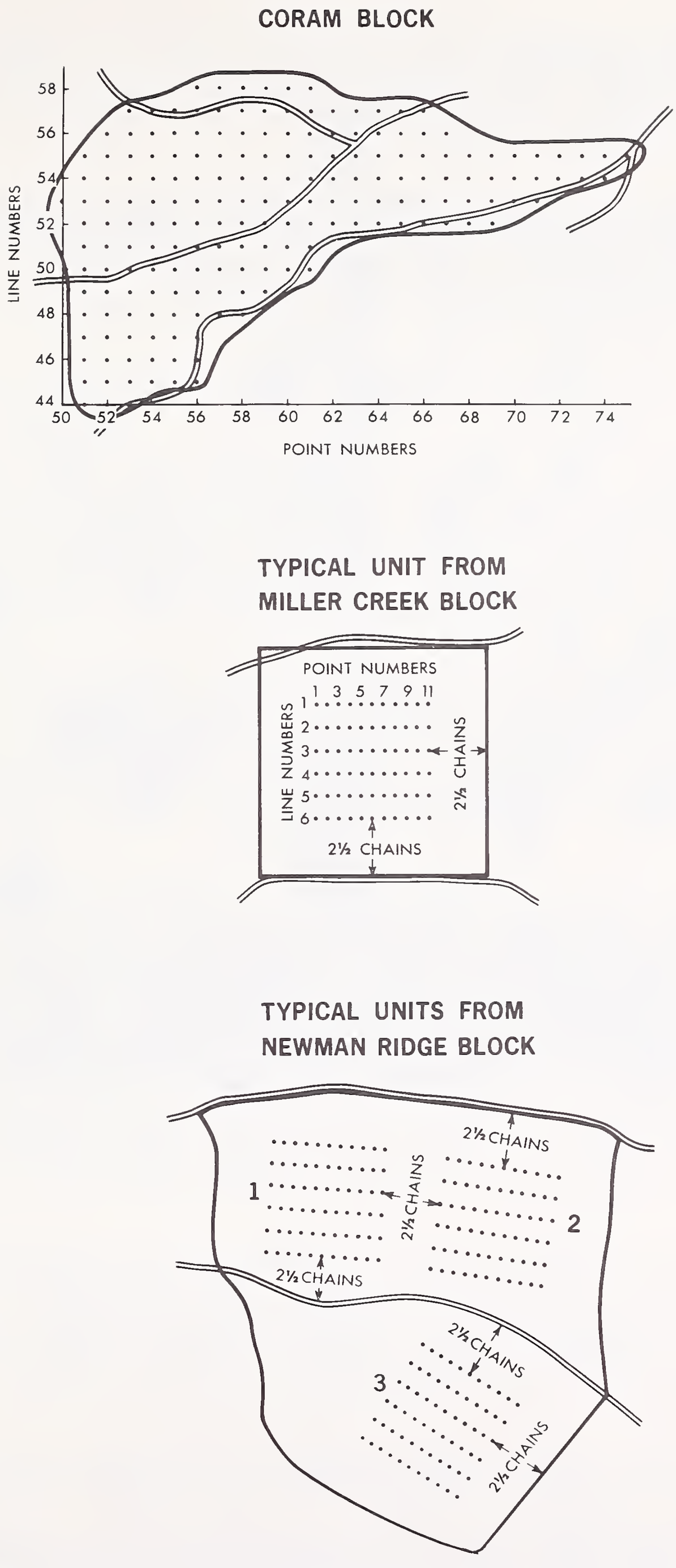

Figure 1.--Three slash fuel sampling patterns. Each has advantages, depending on inventory objectives.

Diameter is always measured at the point of intercept by a sampling plane as shown in figure 2. Material less than 10 cm in diameter occurring as central stems of brush or small trees was grouped, depending on its diameter, with twigs or branches. Fuels larger than 10 cm in diameter were further grouped into classes which are multiples of 10 cm (i.e., 11-20, 21-30, ...81-90 cm).

We gave emphasis to the distribution of needle-bearing twigs because fire spread and intensity in broadcast fires are largely dependent upon the quantity of small diameter fuel particles present. This approach required tolerance of relatively large errors in the numbers of large stems because fuels greater than 10 cm in diameter are rarely as well distributed as are fine fuels. The same is true, to a lesser degree, for fuels between 1 and 10 cm diameter.

The following sections deal with special features of sampling the five previously described fuel classes.

Sampling leaves (needles).--Needle volume, weight, and surface area are important measures of fuel loading. They are most easily expressed as functions of the number of leaf-bearing woody intercepts <1 cm in diameter. To this end we collected 25 twigs of each species from random locations in slash on all exposures. Sample twigs were clipped at their junction with branches or stems larger than 1 cm. If the twig tapered into a larger particle, only that portion less than 1 cm was included in the sample.

All samples were ovendried at 105°C, and then the needles were stripped off. The woody twigs and needles from each sample were weighed separately. One hundred randomly selected, ovendried needles from each sample were then counted out and weighed. From those data, we calculated a needle-to-branch weight ratio for each species, and the average weight per needle. Measurements of specific gravity and volume provided for subsequent conversions of weight to volume and surface area for all needles on the sampled area.

Sampling duff.--Duff is both a major source of fuel and the object of fire treatment. Duff depth and bulk density are important parameters that vary with slope, site quality, and exposure.

Using a cylindrical steel soil sampler we collected 12.7-cm (5-inch) diameter duff cores at 25 random locations on each of four exposures at both Miller Creek and Newman Ridge; and we measured the depth to mineral soil (to the nearest 0.5 cm) along opposing sides of the hole created by the soil sampler. The duff cores were ovendried to a constant weight at 105°C to provide data necessary in calculating bulk density and depth/weight ratios for each sample. The weight of incorporated mineral matter was subtracted from the total dry weight after burning each sample at 600°C and weighing the mineral residue to arrive at total organic content.

Regressions of duff weight on depth were developed for each cardinal exposure on each experimental block. The regression equations were sufficiently different to warrant stratification of duff data by exposure. These equations are specific to the blocks sampled for this study and may not apply to duff from other locations. Subsequently, the duff depth was sampled in the field, and duff weight per unit of area was computed by using the depth-weight regression equation that applied.

Sampling twigs (<1 cm).--The sampling of woody material less than 1 cm in diameter (twigs) consists of two phases: First, the number of particles intercepted by a 1-m-long vertical plane is estimated at all of the sample points on a unit. Second, fuel particles are actually counted on a randomly selected subsample of these points. The probability that a sample point will be chosen for counting is made proportional to the number of twigs estimated at that point (Cochran 1963).

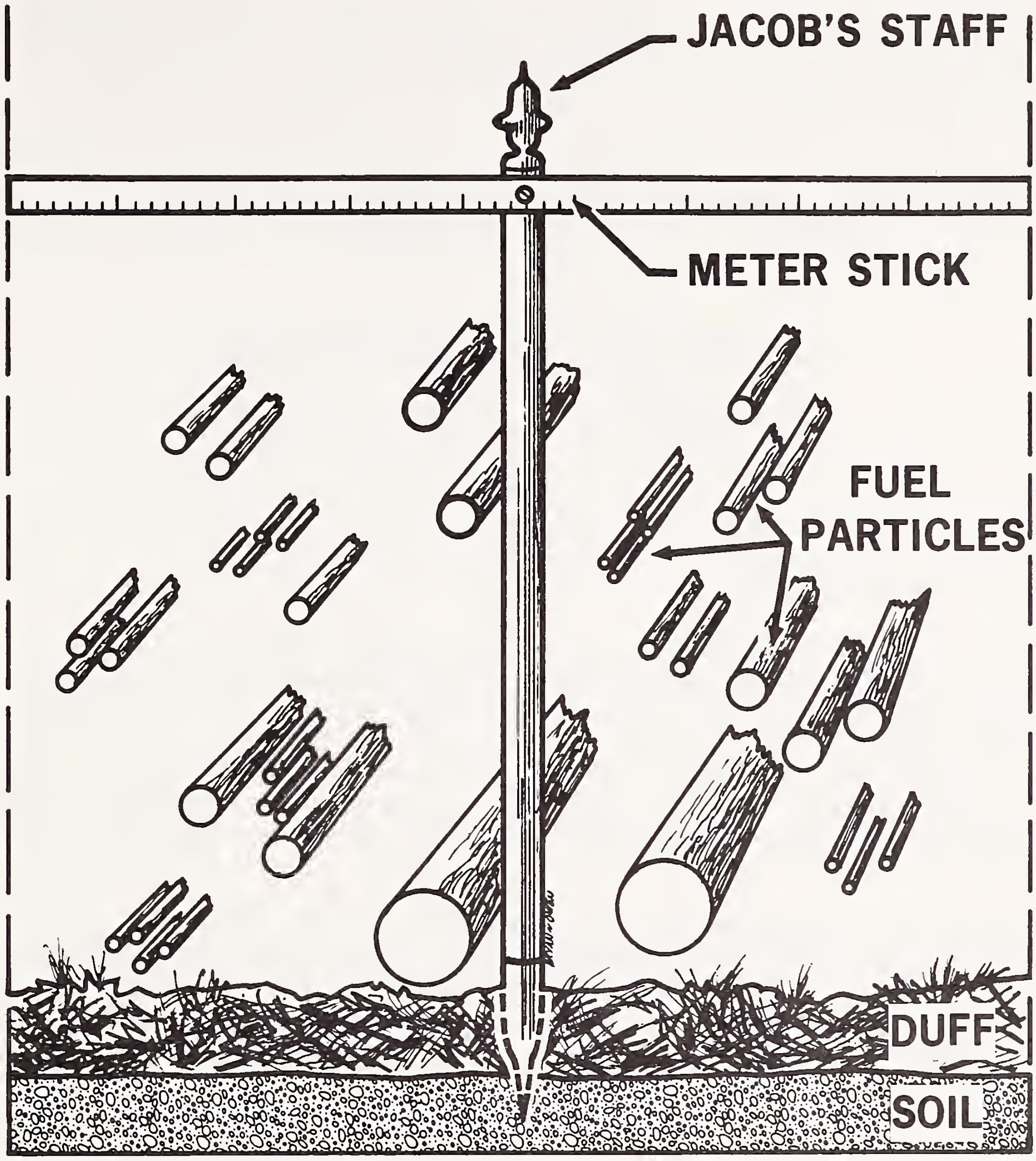

Figure 2.--The diameters of particles intercepted by the imaginary sampling plane are always measured at the points of interception with the plane.

Our sampling scheme follows:

1. A set of sample points is distributed systematically over the study unit (plot).

2. A series of random number lists having different mean values is prepared. Each field unit is assigned an ocular estimate of the average number of twigs per sample point. Based on this ocular estimate, a list is selected from the series for subsampling that unit.

3. The ratio of points at which counts are made, to the total number of points per unit, is calculated to minimize the sampling variation.

4. An observer uses the expected fuel density, the sampling ratio described in item 3 above, and the list of random integers; and visits each of the sampling points and performs the actual field procedure as outlined in the "Field Procedure" section of this text.

Sampling branches (>1 cm, <10 cm).--Woody particles with diameters between 1 and 10 cm were classed as branches. Generally, we found fewer than 10 particles in this size class intercepted each of our 1-m-long planes. Clearly, counting was more efficient than estimating these numbers, so all 1-10 cm intercepts were counted.

Sampling stems (>10 cm).--We tallied approximately one intercept greater than 10 cm per sampling point. Different utilization standards would undoubtedly cause this to change. These intercepts were cull logs, long butts, or unmerchantable boles and tops. Each stem was tallied by its diameter (to the nearest 10 cm) at the point of its interception with the 1-m sampling plane.

Collateral Measurements and Computations

Specific gravity.--Woody fuels were not weighed in the field; rather, fuel volumes were computed from the twig, branch, and stem sample data gathered in the planar intercept sampling. Conversion from volume to weight requires values of specific gravity for each size and species of woody fuel sampled. We used published data (USDA Forest Service 1955) for specific gravity of stems and branches. Specific gravity figures for smaller twigs were lacking, so a number of twigs of each species pertinent to our study were measured and weighed to establish the needed specific gravity values.

Specific gravity determinations were made in terms of ovendry weight. The volume was measured at field moisture levels. Three segments were cut from 25 twigs of each species. These segments, at least 2 cm long, represented the base, midpoint, and tip sections of the twigs. After a period of curing to typical summertime field conditions (7-percent moisture content), the diameters of the segments were measured and each was immersed in mercury. The displacement of mercury was used to determine volume. They were then ovendried and weighed. From these volume and weight measurements specific gravity was computed.

Mean diameters.--Mean diameters for material 0-1 cm in diameter (twigs), by species, were required for use in volume calculations. Needle-bearing twigs, as previously described under "*Sampling Leaves*," were used. The total lengths of the twigs were measured, along with their diameters, at 10-cm intervals. The diameters of tip segments less than 10 cm long were measured at the segment midpoint. Over 10,000 diameter measurements were made. From these measurements a weighted, average green diameter was calculated for each species. Samples were gathered from two widely separated experimental blocks, and we found no significant differences in mean diameters between the blocks. Therefore, the data for each species from both blocks were pooled.

In order to compute mean diameters of branch-size material (1-10 cm), line transects were tallied in the field. On both experimental blocks, the diameters of over 100 branches of each of seven species were measured along randomly oriented lines. As with twigs, branch mean diameters were not significantly different between blocks.

Surface areas.--Twigs, branches, and stems were assumed to be circular cylinders with diameters equal to the mean diameter of their respective size class. We followed procedures outlined by Brown (1970) to determine the surface area-to-volume ratio of leaves and needles.

Volume computations.--The 1-m-long vertical sampling planes were randomly oriented in relation to the direction of slope. They were bounded beneath by the upper surface of the organic forest floor (litter surface), and above by the highest fuel particle passing through the plane. Assuming the fuel particles are circular in cross section and pass through the plane at all angles, we used the following formula to compute volume of fuel sampled on the study units (derivations and discussion of theory were fully covered by Brown [1971]):

$$V = L \frac{nd^2\pi^2}{8}$$

where:

V = volume, cm^3

L = length of fuel particles at right angles to the plane (set at 1 m)

n = number of intercepts, by species and size class

d = mean diameter of the species and size class, cm

Computation of volume of fuel is done in a computer program. As an example, the volume of fuel on a unit, in the 1-10 cm class, is computed as follows:

$$V = \sum_{i=1}^{9} Vi \qquad = LT \frac{\pi^2}{8} \sum_{i=1}^{9} D_i^2 P_i$$

where:

V = volume of fuel on the unit in the 1-10 cm class

Vi = volume of fuel on the unit, in the 1-10 cm class, for individual species (i)

L = assumed length of all intercepts (1 m)

D_i^2 = the average square diameter of the i^{th} species in this size class

i = a number code (1-9) for species

T = the number of intercepts in the 1-10 cm size class for this unit

P_i = the percent frequency for the i^{th} species

FIELD INVENTORY PROCEDURES

Once the optimum number of sampling points for any given inventory job has been determined, a satisfactory distribution of the points is necessary. Our experience has been that a reasonably uniform, rectangular grid is most suitable for efficient, objective sampling in logging slash. As previously described, our final arrangement on each 2 1/2-acre plot was a grid with 1- by 1/2-chain intervals, for a total of 66 sample points.

Field Equipment and Supplies

Following is a list of necessary items to be carried by inventory crews. While not bulky, they are best stored in a many-pocketed vest. Small items should be tied to the vest to prevent loss in the slash.

Item	*Use*
1. Hand compass that is declination-corrected, and has 360° markings.	Plot layout and transect exposure measurement.
2. One-chain trailer tape with topographic corrections.	Plot layout and measurement of distances between transects.
3. Abney level marked with percent scale.	Slope measurements for chaining adjustments and to record slope percent at each transect.
4. Jacob's staff, attached meter stick, and level.	Planar transect establishment and delineation of edges.
5. Port-a-Punch board, stylus, and cards.	Data recording.
6. Steel pocket tape.	Measure slash depth, duff depth, and large log diameters.
7. Gaming die in clear plastic container.	Random orientation of transects.
8. Pocket-size venier calipers.	Measure marginal twig diameters.
9. Random number list.	Determining whether 0-1 cm intercepts must be counted.

Laying Out the Grid

It is usually most efficient to lay out the sampling grid prior to any inventory work. Inventory personnel must exercise great care to avoid bias in the location of the grid intersections. Each intersection is a sample point, and the quantity or position of slash present must not influence judgment about point location.

Sampling a Point

Step 1: Erect a Jacob's staff and attached meter stick (fig. 3) at the sample point.

Step 2: Roll the die to determine meter stick orientation. Multiply die value by 30°, which gives the angle the meter stick should make with the contour. The meter stick is then leveled.

Step 3: Record the exposure of each sample point to the nearest 10°N. azimuth.

Step 4: Measure slope with an Abney level and record to nearest 10 percent.

Step 5: Record duff depth to the nearest 1 cm from the mean of three measurements. Normally the duff measurements will be made at points below the 0-, 50-, and 100-cm divisions of the meter stick. (Duff depth is the vertical distance from the undisturbed duff surface down to the surface of mineral soil.)

Step 6: Slash depth is the vertical distance from the duff surface to the highest fuel particle passing through the sampling plane. Measure this depth with the steel tape and record to the closest decimeter.

Step 7: Discontinuities in the duff are observed along the line of intersection of sampling plane with the earth. The portion of this line comprised of bare mineral soil is recorded to the nearest 10 percent.

Step 8: Up to three tree species contributing to the slash at a sampling point are identified and ranked in order of their percent of contribution. Proportions of aerial fuels in the 0-1 cm diameter class for the two most common species present are recorded to the nearest 10 percent. It is assumed that a third species, if noted, makes up the remaining percentage. A more extensive and precise listing may be designed and used if needed for fuels at other locations.

Step 9: Next, tally number of twigs (0-1 cm). Make an ocular estimate of the number of twigs intercepting the sampling plane. Record this estimate, then read the next number on the list of random numbers.

If the random number is less than the estimated number of intercepts, but not zero, make a count of the twigs. *Always* count the sample point when the estimate of fuel density exceeds a preassigned, estimated maximum fuel density for the unit, regardless of the value of the next random number.

Step 10: Then count the number of branches (1-10 cm diameter) and record.

Step 11: Measure, at the point of interception with the plane, the intercepts larger than 10 cm in diameter and record the diameter to the nearest decimeter. (If the centerline of an intercept passes through the sampling plane, it is recorded.)

Step 12: Record the appropriate code if the sampling point falls on a skid road or other cultural feature.

Figure 3.--Sampling planar transects in interior Douglas-fir logging slash. Note the Jacob's staff base for the meter stick.

FIELD DATA RECORDING SYSTEM

For our purposes in the field, punching of data on prescored, 40-column machine cards proved most efficient. IBM Port-a-Punch cards and accessory holders were used. We also found that overprinted legends on the field cards reduced errors in reading and punching. Sample cards and holder are shown in figure 4.

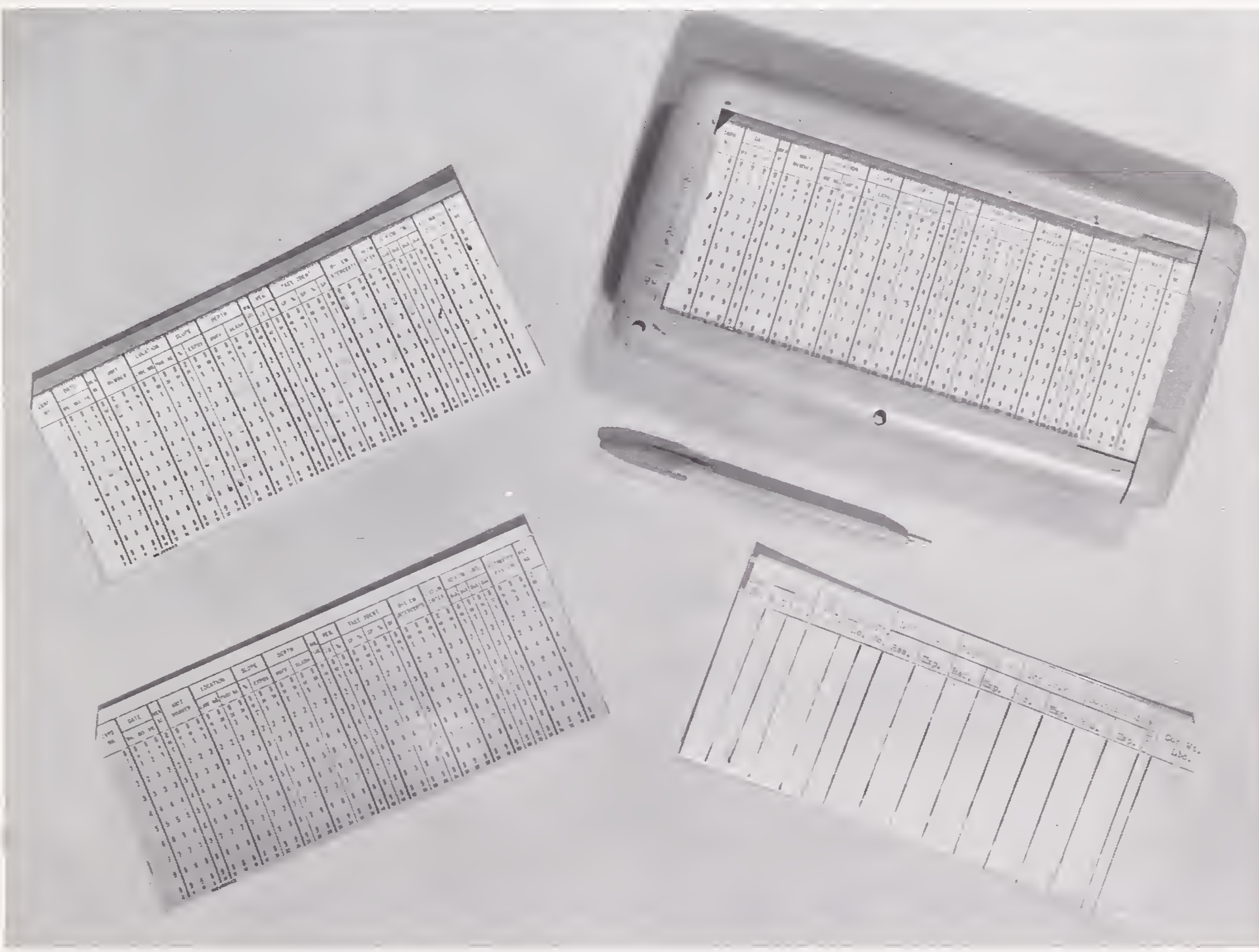

Figure 4.--Port-a-Punch cards, holder, overlay, and stylus. Note the blank prescored cards on the left. A scribed plastic overlay at lower right designates columns.

REDUCTION OF DATA

Preparation of Auxiliary Data

Computation of sampling statistics for twigs (<1 cm obtained by 3P subsampling).--We define density of twigs as the average number of 0-1 cm fuel intercepts per unit of area encountered on a plot (unit). Density and its variance are useful statistics in comparing the fuel loading of one plot with another. 3P fuel sampling should be designed to minimize the variance of the density estimates.

The estimated density of twigs (D) is the corrected total number of 0-1 cm intercepts for all sample points divided by the number of sample points and multiplied by an area conversion factor (F). It is computed as follows:

$$D = F * \left[\frac{1}{n} * \sum^{n} YKPI\right] * \left[\frac{1}{m} * \sum^{m} \left(\frac{YI}{YKPI}\right)\right]$$

where F is the conversion factor from a 1-m transect to a unit of area.

The notation used in this section follows that of Grosenbaugh (1965). T is the estimated total number of twigs for all sample points on a plot, corrected for observer bias. That is:

$$T = \sum^{n} YKPI * \frac{1}{m} \sum^{m} \left(\frac{YI}{YKPI}\right)$$

where:

n = the number of sample points on the plot
YKPI = the estimate of twigs at each sample point
YI = the count of twigs at each sample point where a count was made
m = the number of points at which counts were made

An approximation for the variance of the estimate T is VT.

$$VT = n^2 * \left\{\left(\overline{\frac{YI}{YKPI}}\right)^2 * V\left(\overline{YKPI}\right) + \left(\overline{YKPI}\right)^2 * V\left(\overline{\frac{YI}{YKPI}}\right) + 2\left(\overline{YKPI}\right) * \left(\overline{\frac{YI}{YKPI}}\right) * COV\left(\overline{YKPI}, \overline{\frac{YI}{YKPI}}\right)\right\}$$

where $\overline{\frac{YI}{YKPI}}$ is the mean ratio of the count to the estimate, and $\overline{YKPI}$ is the mean estimate, and V $\overline{YKPI}$ is the variance of the mean estimate, and V $\overline{\frac{YI}{YKPI}}$ is the variance of the mean ratio, and COV $\overline{YKPI}, \overline{\frac{YI}{YKPI}}$ is covariance of mean estimate to the mean ratio. The sample estimates of the above variances and the covariance are given below.

$$V\left(\overline{YKPI}\right) = \frac{n}{n-1}\left\{\sum^{n}\left(YKPI\right)^2 - \frac{\left(\sum^{n} YKPI\right)^2}{n}\right\}$$

$$V\left(\frac{\overline{YI}}{YKPI}\right) = \frac{m}{m-1}\left\{\sum^{m}\left(\frac{YI}{YKPI}\right)^2 - \frac{\left(\sum^{m}\frac{YI}{YKPI}\right)^2}{m}\right\}$$

$$COV\left(\overline{YKPI}, \frac{\overline{YI}}{YKPI}\right) = \frac{m}{m-1}\left\{\sum^{m} YI - \frac{\sum^{m} YKPI \sum^{m}\frac{YI}{YKPI}}{m}\right\}$$

Generating the random number table.--For use in this sampling scheme, it is advantageous to use the computer program "THRP" by Grosenbaugh (1965) to prepare the list of random numbers for each plot. The program input parameters are defined by Grosenbaugh in terms of the average expected YKPI for the plot, the desired number of sample points, and the desired number of subsample points (points at which the 0-1 cm particles are counted).

Preliminary sampling.--For each unit inventoried, a sample density (the average number of pieces of fuel per sample point) and the variance of the density are computed for each fuel size class. Using these two statistics, we have a point estimate of the fuel load on each plot *and* an estimate of the variation in fuel placement on the plot. Confidence statements about the fuel density, or tests for difference between plots, can also be constructed from these statistics.

Data Processing Computer Programs

Because the amount of data accumulated by slash fuel inventory is so massive, machine processing is necessary. We compiled plot summaries having estimates of average fuel density and standard error of that estimate, by fuel type. It may be of interest to readers that we employed the inventory system to inventory the fuels again after fire treatment. Data from both the preburn and postburn inventories were processed with the same programs. Because the programs were written specifically for this study they should not be considered to be general purpose summary programs and may not be suitable for use with other sampling schemes. However, for those interested, the programs and ADP card codes are on file at the Northern Forest Fire Laboratory, Missoula, Montana, in mimeograph form, entitled "Data Log, ADP Card Codes, and Programs."

The three major programs used for processing our field inventory data are briefly described below:

1. *Fuel Inventory Program, "3P".*--The input to this program is preburn inventory data arranged by plot. The program computes, punches on cards, and prints out an adjusted estimate of the average density of fuels in the 0-1 cm size class. Other statistics, such as species distribution, are also printed out.

2. *"Tally-2".*--This program, together with its subroutines, averages all fuel sizes except the 0-1 cm class. Preburn and postburn inventory data are input.

3. *"FIRESUM".*--This program computes estimates of fuel volume, surface area, and weight by size class. Its input is the output from "3P" and "Tally-2" plus other data on species characteristics.

INVENTORY RESULTS

Table 1 is an example of fuel inventory summary data obtained by methods outlined earlier--in this case, fuel weight classified by size and exposure. Alternatively, either fuel volume or surface area by species could have been presented along with measures of central tendency.

Table 1.--*Fuel weights before burning by size class and exposure*

Exposure	Size classes							
	0-1		1-10		10+		Needles	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Kilograms/square meter							
	MILLER CREEK							
North	0.30	0.07	2.17	0.73	24.17	6.13	0.37	0.09
East	.31	.05	2.31	.61	21.28	4.17	.37	.07
South	.26	.05	2.29	.59	24.11	5.59	.31	.07
West	.28	.08	1.92	.57	22.67	5.01	.33	.09
Average	.29	.07	2.17	.67	23.06	5.35	.35	.09
Range								
Low unit	.19		1.03		11.87		.19	
High Unit	.51		3.76		33.65		.59	
	NEWMAN RIDGE							
North	.24	.07	1.93	.29	24.18	6.42	.38	.14
East	.17	.05	2.23	.67	18.95	3.36	.20	.06
South	.32	.08	3.61	1.13	18.68	4.30	.44	.21
West	.29	.10	3.09	1.23	22.04	4.64	.38	.18
Average	.26	.09	2.71	1.09	20.96	5.05	.35	.18
Range								
Low unit	.11		1.56		13.94		.12	
High Unit	.42		4.77		34.20		.70	

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- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)